

[0001] AUTOMATED MANUFACTURING EQUIPMENT AND PROCESS
FOR ASSEMBLY OF ORDERED OPTIC FIBER ARRAYS

[0002] BACKGROUND

[0003] The present invention is directed to the assembly of ordered optic fiber arrays. More particularly, the invention provides equipment and a process to manufacture ordered, multiple ended optic fiber arrays.

[0004] As a result of progressing technology, the need to create high-speed optical data interconnections has increased. Opto-electronic components used in high speed communications have become more prevalent. Connections between such opto-electronic components has typically been made through separately connected optic fibers. This has the disadvantage of increased routing and installation time requirements. It has also been known to use a machine to place a number of fibers on an adhesive coated substrate to form a single layer matrix with the desired optic fiber routing in a semi-rigid card form. The resulting product, however, is prone to micro-bending sensitivity and offers little routing flexibility after construction. It is also limited in size and increases the potential for damage to sensitive electronic components by overheating due to reduced air flow caused by the substrate.

[0005] The increase in the type and number of opto-electronic components has necessitated the creation of multiple ended ordered optic fiber arrays which may extend one-two meters or more to link these components. The differing features of opto-electronic components and the large number of potential arrangements of these components often necessitates special optic fiber array designs that allow some routing flexibility, while also allowing for easier and faster handling during installation.

[0006] The assignee of the present invention developed a method by which multiple ended ordered optic fiber arrays were manually assembled using ribbons of optical fibers which were manually placed into holders on a first side of the array. A chemical solution was used to remove the binding agent holding the ribbonized fibers together on the opposite side of the array. The ends of the fibers of the formerly connected ribbon are then manually separated and re-ordered into different end fiber array configurations, as needed based on particular routing requirements. The re-ordered ends are then coated with a binding agent. A multiple ended optical fiber array was formed upon the curing of the binding agent having the required routing for a particular application and having both flexibility for placement and convenience during assembly since multiple connections can be made at the same time. Because this process was manual, excessive time was spent in manually re-ordering and/or rerouting the output fibers to create multiple ended fiber optic arrays. This can result in low production rates, high cost, and poor quality control.

[0007] It would be desirable to create a more efficient method to form multiple ended ordered optic fiber arrays. It would also be desirable to create a methodology for forming differing types of multiple ended ordered optic fiber arrays to be used in different applications. It would also be desirable to create an apparatus that can quickly and reliably manufacture multiple ended ordered arrays of optical fibers in various desired configurations.

[0008] SUMMARY

[0009] A manufacturing process for producing a cross-connected matrix of optical fibers. The process includes providing a plurality of optic fiber paths on a fiber positioning fixture. At least one optic fiber is sequentially routed on the positioning fixture by arranging the at least one optic fiber into n fiber runs having at least two input groups based on a predetermined map, with at least m of the n fiber runs having a first end in one of the input groups, where m is an integer defined by $2 \leq m \leq (n-1)$. The at least one optic fiber is also

arranged into at least two output groups based on the predetermined map, with at least one of the m fiber runs having a second end in a different output group than the output group of another of the m fiber runs. The first ends of the fiber runs in the input groups are ribbonized as are the second ends of the fiber runs in the output groups.

[0010] In another aspect, an apparatus for producing a cross-connected array of optical fibers is provided. The apparatus includes an optic fiber positioning fixture and fiber guides for holding placed fibers. At least one optic fibers is placed on the optic fiber positioning fixture by a fiber dispensing head connected to a moveable positioning system. The positioning system is controlled by a programmable controller which controls movement of the optic fiber dispensing head to place fiber according to a predetermined map.

[0011] BRIEF DESCRIPTION OF THE DRAWING(S)

[0012] The foregoing summary as well as the following detailed description of the preferred embodiments will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, two preferred embodiments are shown. However, it should be understood that the invention is not limited to the precise arrangements shown.

[0013] Figure 1 is a perspective view of an ordered array optic fiber positioning apparatus in accordance with a first embodiment of the invention.

[0014] Figure 2 is a perspective view of an optic fiber positioning fixture in accordance with the present invention.

[0015] Figure 3 is a perspective view of generally vertical fiber grippers used in the fixture of Figure 1.

[0016] Figure 4 is a perspective view of generally horizontal fiber grippers which can be used in conjunction with the optic fiber positioning fixture of Figure 1.

[0017] Figure 5 is a side view of an assembly line for producing cross-connected matrices of optical fibers.

[0018] Figure 6 is a perspective of a plurality of fiber grippers which form multiple optic fiber paths.

[0019] Figure 7 is a view of a modular pallet carrier which can be used in the present invention.

[0020] Figure 8 is a perspective view of the optic fiber positioning fixture with end posts used for routing a single optic fiber along multiple optic fiber paths.

[0021] Figure 9 is a perspective view of a plurality of optic fiber positioning fixtures used for extended routing of optic fibers.

[0022] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0023] Referring to Figure 1, an optic fiber positioning apparatus 10 for producing a cross-connected matrix of optic fibers in accordance with the present invention is shown. The optic fiber positioning apparatus 10 includes an optic fiber positioning fixture 12, shown in detail in Figure 2. The fixture 12 includes fiber guides 14 located thereon which are adapted to hold optic fiber runs, as will as be described in detail below. Each of the fiber guides 14 is preferably removably connectable to the fixture 12 via slots 13 located on the fixture 12. The guides 14 preferably include a guide slot 15 having a width approximately equal to a diameter of the optic fiber being arranged, and guides 14 with slots 15 of different widths may be provided for different sized optic fibers.

[0024] As shown in detail in Figure 2, preferably posts 16 are provided in a transition area between the sets of guides 14 located on opposite sides of the fixture 12. The posts 16 provide a turning radius transition for the optic fibers that are positioned in the fixture 12. Optic fiber runs 17, for example such as those shown in Figures 1 and 2 are preferably placed along a path formed by two guides 14 located on one side of the central transition area, the posts 16 located in the transition area and guides 14 located on the opposite side

of the transition area. A single optic fiber run 17 is shown in Figure 1, and a plurality of guide sets 14 are shown positioned on the fixture 12 in Figure 2 form multiple paths for multiple fiber runs.

[0025] An optic fiber dispensing head 19 is connected to a moveable positioning system 18 located in proximity to and generally over the optic fiber positioning fixture 12, which is located on a support surface 20. While the positioning system is located above the fixture 12 in the preferred embodiment, it is also possible for the fixture 12 to be mounted in a different orientation and the positioning system 18 being located in a corresponding location such that it can move in at least three dimensions (x, y, z) relative to the fixture 12.

[0026] In the first preferred embodiment, the positioning system is a gantry 18 which traverses the support surface 20 of the apparatus 10 in a first direction along guide rails 22. The dispensing head 19 can be moved transversely along the gantry 18 in a second direction, and may be moved up and down in a third direction. It is also possible for the dispensing head to be rotatable about the generally vertical movement axis to aid in routing the fiber.

[0027] As shown in Figure 1, the moveable positioning system 18 is preferably connected to a programmable controller 26 to control movement of the optic fiber dispensing head 19 to place the fiber runs 17 according to a predetermined map. The predetermined map is defined by a user and programmed in the controller 26, based upon the particular application. The number of input groups 34 and output groups 36 of fiber runs 17 is programmed, along with the specific routing of the individual fiber runs 17 from the input groups 34 to the output groups 36. Each optic fiber run 17 is placed in one of the plurality of optic fiber paths defined by the guides 14 and the posts 16. The optic fiber which is dispensed by the dispensing head 19 to form each of the optic fiber runs 17 may be cut into separate pieces after each run is placed, as shown in Figure 2 or may be routed to form a plurality of optic fiber runs 17, as shown in Figure 7, prior to the optic fiber being cut to form the individual runs 17 grouped in the respective input and output groups 34, 36. The ends of the fiber runs 17 are specified as being located in "input" and "output" groups

for the sake of establishing a naming connection, and those skilled in the art will recognize that this is not intended to mean that the fiber run ends in either of the groups 34 or 36 are limited to receiving or emitting optic signals, and the fiber ends in both groups can receive and/or transmit optic signals.

[0028] Referring to Figures 3-5, the guides 14 may be placed vertically or horizontally, as shown. It is also possible for additional posts 16 to be provided in the central area, as shown in Figure 5, to assist in routing the optic fiber along the paths in order to define a plurality of optic fiber runs 17.. The guide slots 15 are preferably sized to be approximately equal to the diameter of the fiber being placed so that the fibers can be held in order in a generally flat linear array within the guides 14.

[0029] As shown in Figure 1, a coating application system 24 may be provided on the moveable positioning fixture 18. After the at least one optic fiber has been routed along the desire paths, the coating application system 24 is used to coat the input and output groups 34, 36 of the fiber runs 17 with an adhesive to hold the fiber ends together such that arrays of fibers are formed. The preferred coating system uses a UV acrylate. However, any other suitable coating which would ensure adhesion of the optic fibers and prevent micro bending would be suitable. The coating may be cured using UV lamps, 34 depending upon the coating system being utilized. The process of coating and curing the optic fibers into defined ribbons allows for easier handling of the cross-connected matrix of optical fibers produced by the present invention during installation between different opto-electronic devices.

[0030] Referring now to Figures 6-8, a second preferred embodiment 110 of an apparatus for producing a cross-connected matrix of optical fibers is shown. The apparatus 110 is similar to the apparatus 10. However, as shown in Figure 6, the support surface 120 is a moving conveyor belt which can be used to move the fixture 112 between a plurality of processing positions. The fiber optic positioning fixture 112 is placed upon the conveyor 120 which is connected to the programmable controller 126. The conveyor 120 moves the

fiber optic positioning fixture 112 from a first position, where the dispensing head 119 located on a moveable positioning system 118 is used to route the optic fiber on the fixture 112, to a second position where a coating system 124 applies a coating to at least the ends of the optic fiber runs. The coating system 124 is preferably mounted on a moveable positioning system 138 so that the material can be applied to the optic fiber runs in only the desired locations. The conveyor 120 then carries the fixture 12 with the coated optic fiber runs to a coating curing system 140 which is also mounted on a movable positioning system 142. The coating curing system 140 is moved by the positioning system 142 such that UV light is applied to the coating in the desired locations.

[0031] Elevators 146, 148 are preferably provided at either ends of the conveyor 120. First elevator 146 receives the fixture 112 with the cross-connected matrix of optic fibers thereon and delivers it to a return conveyor 150. The return conveyor 150 delivers the fixture back to the beginning of the conveyor 120 where the second elevator 148 elevates it to a work station position where the cured device can be removed for further processing.

[0032] Referring to Figure 6, the fixture 112 is shown in more detail. The fixture 112 preferably include a base plate 150 with removable locator plates 152 located thereon. The locator plates 152 include guides 114 which are mounted in fixed positions. Multiple plates 152 may be provided such that different guide configurations can be quickly and easily positioned on the fixture 112 for more flexible production operations. Preferably, the guide-plates 152 can be plugged in the base plate 151 using a locator pin-hole arrangement. However, other keyed fit arrangements may be used. Turning posts 116 as well as other optic fiber guides, such as a comb arrangement 119 which are universal are preferably mounted in the central area of the base plate 151.

[0033] Referring to Figure 8, the fixture 112 is shown having an optic fiber 60 routed along multiple paths in order to form a plurality of fiber runs 117. In accordance with one aspect of the present invention, wrapping posts 164 are located on opposite sides of the optic fiber positioning fixture 112. This allows a single optic fiber to be routed along the paths

in order to form multiple optic fiber runs 117 without the need for cutting each individual optic fiber run 117 into a separate piece upon routing. This allows for easier tensioning of the optic fiber within the optic fiber runs 117 since a constant tension can be maintained on the optic fiber by the dispensing head 119. Alternatively, the optic fiber from the dispensing head 119 can be cut upon the completion of each fiber run 117 during the production of a cross-connected matrix of optic fibers. As shown in Figure 8, the guides 114 closest to the posts 116 have been replaced with the universal comb structure 119 having a plurality of slots located thereon. Alternatively, separate guides 14 could be utilized.

[0034] The finished routing of the optic fiber is then moved along with the fixture 112 to the coating and cure stations. Once the stacked ends of the optic fiber runs 117 have been adhered together and cured, the excess fiber which was wrapped around the parts 164 is cut off to leave a plurality of ribbonized ends.

[0035] Referring to Figure 9 it is also possible to provide a plurality of optic fiber positioning fixtures 112, 212, as shown. This allows for multiple cross over positions and different length ribbons to be formed for extended routing paths.

[0036] A manufacturing process for producing a cross-connected matrix of optic fibers will now be described in connection with the preferred apparatus 10, 110, as described above. A plurality of optic fiber paths are preferably defined on a fiber positioning fixture 12, 112. This may be accomplished through the use of the guides 14, 114 and/or a combination of the guides 14, 114 and the combs 119, in combination with the posts 16, 116 located in the central area of the fixture 12, 112. At least one optic fiber 60 is sequentially routed on the optic fiber positioning fixture 12, 112 by arranging the at least one optic fiber 60 into n fiber runs 17, 117 having at least two input groups 34 based on a predetermined map, which is preferably programmed into the controller 26, 126. At least m of the fiber runs 17, 117 have a first end in one of the input groups 34 where m is an integer defined by $2 \leq m \leq (n-1)$. The least one optic fiber 60 is routed into at least two output groups 36 based on the predetermined map through the moveable positioning system 18, 118 moving the

dispensing head 19, 119. At least one of the m fiber runs 17, 117 has a second end which is in a different output group 36 than the output group 36 of another of the m fiber runs 17, 117. This allows a specific routing to be achieved which allow signal transmission from one or more of the input groups 34 to one or more of the output groups 36 in a desired fashion. The first ends of the fiber runs 17, 117 are ribbonized in the input groups 34 and the second ends of the fiber runs 17, 117 are ribbonized in the output groups 36 by the application of an adhesive and curing the adhesive. This is preferably accomplished using the coating system 24, 124. In the case of a UV acrylate coating system, preferably a curing station is provided for curing the coating using UV light. This results in a cross-connected matrix of optic fibers in which the first ends of the optic fiber runs 17, 117 in at least one of the input groups 34 are arranged in a $1 \times r$ array where r is an integer greater than or equal to two and the second ends of the optic fiber runs in at least one of the output groups 36 are arranged in a $1 \times s$ array where s is an integer greater than or equal to two. The optic fiber may be routed through the defined paths as a single continuous optic fiber which can be wrapped around one or more turning posts 164 located beyond the guides 14, 114 on the positioning fixture 12, 112. Alternatively, the individual optic fiber runs 17, 117 may be placed as separate pieces of optic fiber and held in position. This may require additional grippers which maintain tension on the optic fiber runs 17, 117 after they have been placed.

[0037] The invention provides the advantage of automated assembly of cross-connected optic fiber arrays which can be used in optic data transmission system between one or more opto-electronic devices. It also allows the flexibility of having a cross-connected matrix of optic fibers which is flexible and adaptable to different position of the opto-electronic devices being connected.

[0038] While the preferred embodiment of the invention has been described in detail, the invention is not limited to the specific embodiments described above, which should be considered as merely exemplary. Further modifications and extensions of the present

invention may be developed based upon the foregoing, and all such modifications are deemed to be within the scope of the present invention as defined by the appended claims.

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